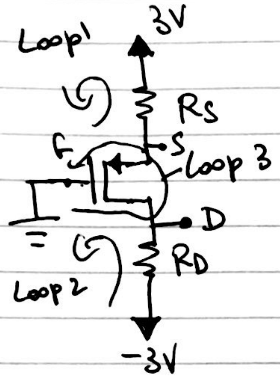
ECE 322L-Spring 2020-Homework 1

Solution



$I_{DQ} = 60\mu A$
$V_{SDQ} = 2.5V$
$V_{TP} = -0.40V$
$K_p = 30\mu A/V^2$.

(a) Designing the circuit is equivalent to determine the values of RS and RD to obtained the desired Q point.

Assume the desired Q point lays in the saturation region: $I_{DQ} = K_p(V_{SGQ} + V_{TP})^2$ $V_{SGQ} > |V_{TP}|$ and $V_{SDQ} > V_{SGQ} + V_{TP}$

$I_{DQ} = 60\mu = 30\mu\,(V_{SGQ} - 0.4)^2 \Rightarrow$

$\Rightarrow V_{SGQ} = 1.814\,V$

$V_{SGQ} > |V_{TP}|$ ✓ $\quad V_{SD,sat} = 2.214\,V \Rightarrow V_{SDQ} > V_{SD,sat}$

The saturation assumption is verified.

Using a KVL at loop 1 (see circuit diagram), we obtain

$$I_{DQ} = \frac{3 - V_{SGQ}}{R_S} = 0.060m \Rightarrow \frac{3 - 1.814}{R_S} = 0.060m \Rightarrow$$

$$\Rightarrow R_S = \frac{3 - 1.814}{0.060m} = 19.77\,k\Omega$$

Similarly using a KVL at loop 2, we obtain

$V_D - R_D I_{DQ} - (-3) = 0$

$$R_D = \frac{V_D - (-3)}{I_{DQ}} \qquad V_D = V_{SGQ} - V_{SDQ} = 1.814 - 2.5 = -0.686V$$

$(V_D + V_{SDQ} = V_{SGQ})$

$R_D = 38.57\,k\Omega \qquad$ (KVL @ Loop 3)

$|V_{TP}|(+5\%) = 0.4 + |V_{TP}| \cdot 0.05 = 0.4 + 0.4 \cdot 0.05 =$
$= 0.4 + 0.02 = 0.42V$
$K_p(-5\%) = 30\mu - K_p \cdot 0.05 = 30\mu - 30 \cdot 0.05\mu =$
$= 30\mu - 1.5\mu = 28.5\mu A/V^2$

Considering the KVL at loop 1 and using the transistor equations (assuming that the transistor remain in saturation), we obtain

$$3 = I_D R_S + V_{SG} = 0.0285\mu (V_{SG} \quad)^2$$
$$3 = I_D R_S + V_{SG} = 0.0285m (V_{SG}^2 - 0.84 V_{SG} + 0.1764)(19.77) + V_{SG}$$

The equation above yields $V_{SG} = 1.849V$

I_D becomes then

$$I_D = 28.5\mu (1.849 - 0.42)^2 = 58.2\mu A$$

$V_{SD} = 6 - I_D(R_S + R_D) = 6 - (0.0582m)(19.77 + 38.57k) =$
$= 2.605V$

V_{SD} is still larger than $V_{SD,sat} = V_{SG} + V_{TP}$. Thus the assumption of the transistor remaining in saturation is correct.